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# Nonflammable Clothing Development Program

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Protective clothing is of major importance in our space program. The authors discuss the requirements, selection, and testing of materials considered for use in the program. The various types of garments worn by astronauts and support personnel are briefly described.

THE flame-resistant substitute materials program for manned spacecraft, a long-range effort of the National Aeronautics and Space Administration, Manned Spacecraft Center (NASA MSC), Houston, Texas, was undertaken to accomplish the following objectives.

- Find flameproof or nonflammable materials for spacecraft to eliminate combustibles from the crew bay compartments,
- Find a direct substitute for fire-prone materials in the spacecraft,
- Improve the characteristics of the substitute materials by development and testing in actual use, and
- Establish a specification for material application based on all qualifying evaluations.

The materials being studied are those which are primarily associated with the personal provisions of the crew and the nonmetallic materials within the habitable areas of the spacecraft. The purpose of the program is to evaluate and develop the latest fibrous, plastic, and elastomeric materials for spacecraft cabin or space environment applications. The facilities used by laboratory personnel have capabilities for testing and evaluating specific physical and functional performance characteristics of materials before, during, and after exposure to simulated space and lunar environment or spacecraft cabin conditions.

National Aeronautics and Space Administration personnel, working with private industry on the substitute materials program for spacecraft application, have critically evaluated the approaches previously used in the application of materials. The present philosophy is to investigate and

determine the merits of a material for a specific application rather than to become involved with an overall specification. For example, if a potential substitute material displays relatively low tear or abrasion resistance, but does not burn and is relatively light in weight, and if it proves satisfactory for the number of times it will be used, then the philosophy is to continue to consider the use of the material in the space program rather than to discard it because of an antiquated and confining specification. Immediate substitution or replacement is not possible for all the areas under study because of the lag in technological techniques.

Materials for evaluation are obtained by continually conducting industry searches for newly developed materials within either the space industry or laboratories for material development and by establishing contracts to develop a material to fulfill the requirements of the spacecraft program.

Present NASA contracts with industry seek new materials to replace fabrics, braids, webbings, threads, filters, insulation, fasteners, mats, and moldable compounds in articles of astronaut apparel, survival equipment, crew provisions, and spacecraft subsystems. Another approach to providing fire protection is to maintain present hardware configurations but to contain the hardware within a fireproof cover of Beta fiber, asbestos, or a metallic substance.

## SPACE SUIT USAGE EXPOSURE ENVIRONMENT

Materials used in space suit applications are exposed to, and must withstand, the rigors of environments much more severe than those normally imposed on standard usage items. These environments can be categorized in two major areas — spacecraft and deep-space environments.

Those materials used only in the spacecraft must be tested primarily for resistance to burning and for lack of toxic offgassing into the breathing atmosphere. These materials can be exposed to as much as 16.5 psia (pounds per square inch absolute) pure oxygen in the command module or to 6.2 psia oxygen in the lunar module. Under the higher oxygen tensions, normally nonflammable items, such as stainless steel fabric, will burn upon exposure to a spark or flame.

Even greater restrictions are imposed on materials that will be used in extravehicular or lunar excursion activities. Materials used for these purposes, in addition to being nonflammable, must withstand the rigors of $10^{-14}$ torr pressure, temperature exposures of $\pm 300°$ F, micrometeoroid bombardment, and impingement by infrared, near and far ultraviolet, and particulate flux solar radiation. Materials are required to remain flexible and strong, and to operate under these severe conditions.

An example of a special material requirement is the space suit helmet visor. The visor must have high transmittance in the visible spectrum and low transmittance in the ultraviolet and infrared regions. The visor must be scratch resistant and must have high impact resistance to protect an astronaut in the event of a fall. In addition, the visor must withstand

temperatures which exceed +300° F in a lunar crater, must withstand thermal stresses of alternate exposures to +300° and −300° F, and must be flame resistant in oxygen environments.

## MATERIALS TESTING

In an attempt to obtain nonflammable garments, it has been necessary to use certain materials the development of which have not evolved to the point where they are acceptable according to standard military or federal specifications. Therefore, a minimal criterion has been imposed. This criterion is that a material not undergo excessive degradation under its anticipated use cycle. Flat sample test results are compared with those from materials having known end-item degradation properties to project probabilities of end-item failures. End-item garments are in all cases fabricated and evaluated prior to acceptance.

The philosophy followed by MSC personnel (Crew Systems Division) to select materials for use in the spacecraft is as follows.

- Regardless of application, any materials now being used that have a replacement immediately available shall be replaced with a nonflammable substitute; for example, metal cover caps for tubes of medicinals have replaced polyethylene caps. If no nonflammable materials exist as a replacement, then obviously no change will be possible. However, as replacement materials are developed, they will be considered for incorporation into the hardware immediately.

- In the event that substitute materials cannot be found for replacement, all flammables must be insulated to prevent self-ignition. This means that if a flammable material is used inside a metal container or rucksack, the container must be insulated in such a manner that the internal temperature will not exceed the ignition point of any of the materials contained within, when tested at a predetermined flame impingement temperature and applicable oxygen pressures within preset time constraints.

Materials testing is broken down into three major categories. These categories are structural properties under ambient conditions; flammability properties; and material degradation under exposure to simulated-lunar thermal, vacuum, and radiation environments.

Testing of ambient environment structural properties is concerned primarily with standard tests such as abrasion, wear, tear, folding endurance, stiffness, permeability, rupture strength, tensile strength, and so forth. Attempts are made to relate flat sample test results with end-item usage degradation.

The primary criterion for materials used in garment fabrication is flammability resistance. Items (such as garments), which occupy a large volume in the spacecraft, are required to be completely nonflammable in a pure oxygen atmosphere at 16.5 psia pressure. They are further tested to verify that a spark in proximity to a heated specimen will not initiate a

flame, and that they will not autoignite when heated. In addition, samples must not, when heated, offgas excessive amounts of toxic products. Flammability tests used in evaluating the flammability properties of a candidate garment material are flame propagation, flash/ignition and autoignition, flame impingement, and short-circuit flammability testing.

To determine the flame propagation rate of a material, samples are mounted vertically in the bell jar shown in Figure 1 or the pressure chamber shown in Figure 2. A nichrome wire, wrapped with a small tissue ignitor, is located at the sample bottom so that, when heated, a small open flame will be generated. After the chamber has been evacuated and back-filled with pure oxygen to the desired pressure, flame propagation of the sample is measured in inches per second.

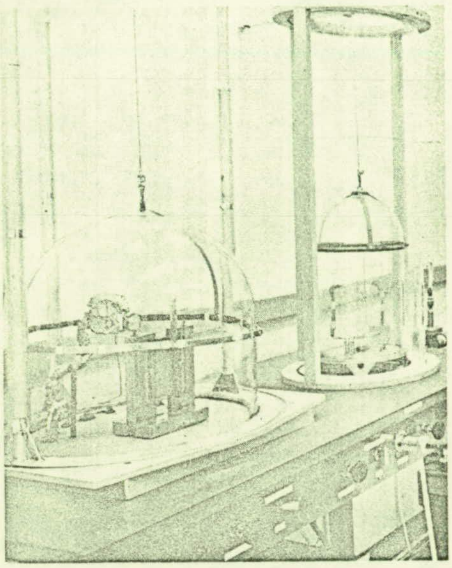

*Figure 1. Bell jars for flame propagation tests.*

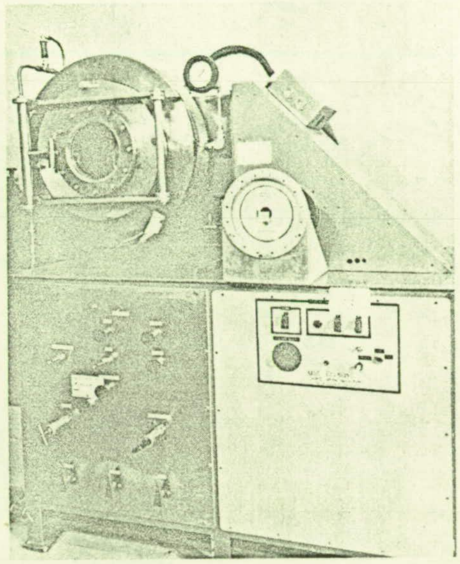

*Figure 2. Pressure chamber for flame propagation tests.*

The autoignition or flash/ignition tester shown in Figure 3 was developed by MSC for determining the flash/ignition or autoignition point of candidate garment materials. The candidate material is mounted in the support shown and covered with a small cylinder, which has a transparent Vicor top. The rate-controlled furnace, shown at the right in the photograph, is placed over the cylinder, and the combined apparatus is placed in the pressure chamber shown in Figure 2. After the system has been back-filled with oxygen, the sample is heated at a prescribed rate by means of a temperature programer attached to the furnace. A 10,000-volt, 40-millijoule spark is periodically initiated at the top of the sample. The temperature at which this spark can cause ignition of the pyrolytic products being evolved by the sample is referred to as the flash point of the sample. If the material is degrading rapidly enough that the flash causes the sample

to ignite, the temperature at which ignition occurs is referred to as the ignition point. If combustion occurs without application of a spark, the temperature at which this ignition occurs is referred to as the autoignition point. These temperatures must all be in excess of 450° F for a material to be considered acceptable for flight usage.

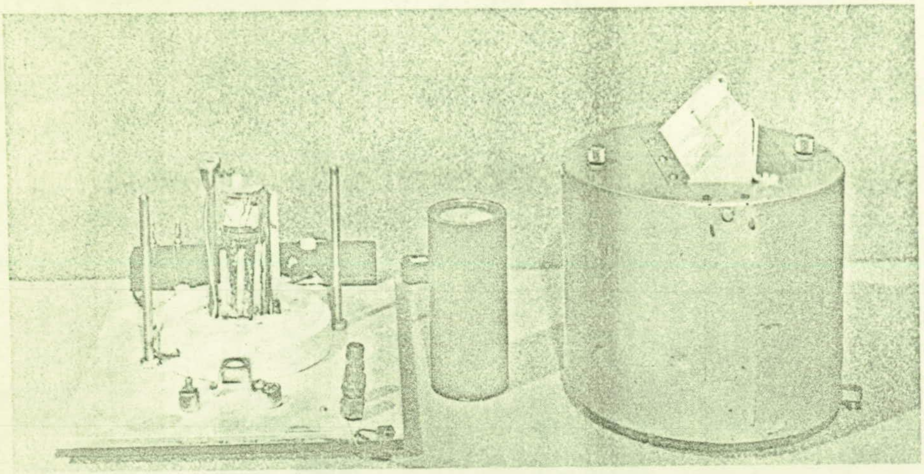

*Figure 3. Autoignition or flash/ignition test equipment.*

A short-circuit flammability tester, developed by MSC, is shown in Figure 4. This tester is used to determine the potential hazard of a flammable material (used in proximity to electrical wiring) in the event of a possible short-circuit failure. A candidate material, such as a flammable within a space suit (e.g., human hair), is mounted on a flat copper electrode and frayed by a maneuverable needle electrode. The source voltage imposed across the electrodes causes a short-circuit arc to be generated across the frayed sample. The potential hazard of the material may be evaluated by measuring the minimum current capable of causing sample ignition.

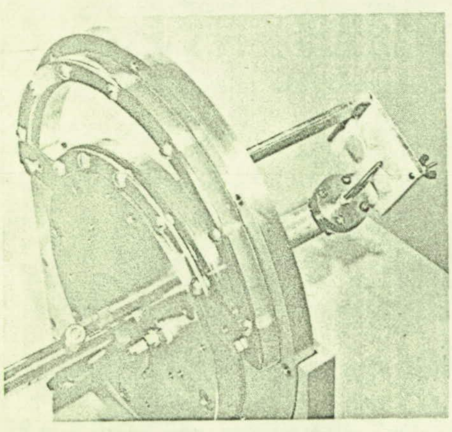

*Figure 4. Short-circuit flammability tester.*

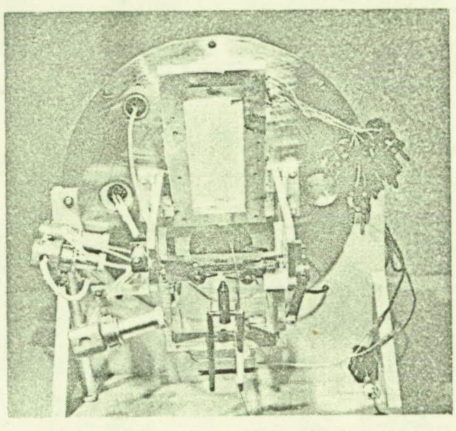

*Figure 5. Flame impingement tester.*

The device used most frequently in garment designs is shown in Figure 5 and was also developed by MSC. This flame impingement tester allows a candidate thermal protection layup to be subjected to a flame of any desired temperature between 1,200° and 2,500° F in a pure oxygen environment. The resulting time/temperature curves throughout the sample can be monitored. An example of the data generated by this device is shown in Figure 6. This curve allows evaluation of the effectiveness of any layer in the composite and of the thermal protection provided, as a function of time, by the composite as a whole.

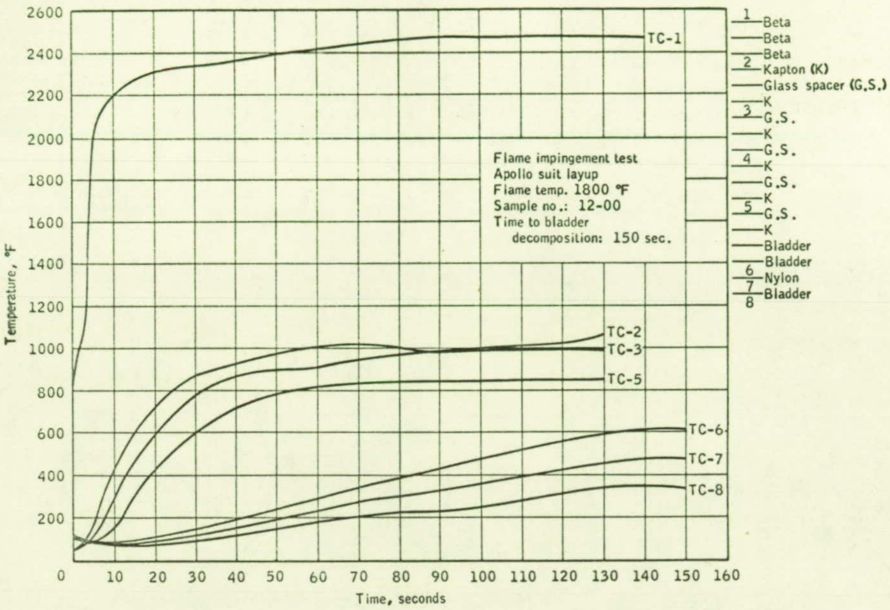


*Figure 6. Data obtained from tests employing the flame impingement tester.*

The flame impingement tester frequently is used in conjunction with the flash/ignition tester for designing thermal layups; the flash/ignition tester indicates the degradation temperature of a material to be covered (such as a space suit bladder); the flame impingement tester determines, for a particular flame temperature, whether this temperature can be obtained.

The final tests, which certain garment materials must withstand, are exposure to simulated lunar surface or orbital environments. Small samples (2 in. in diameter) of the materials considered for use as outer-layer garment materials will be placed in a vacuum chamber and exposed to $\pm 300°$ F temperatures and $10^{-14}$ torr pressures. Samples are then exposed to bombardment by infrared, ultraviolet, radiation and X-ray, electron and proton flux at energy levels simulating actual use conditions. Real-time tests and post-test evaluations will determine the degree of materials degradation. The test format used for garment development is shown in Figure 7.

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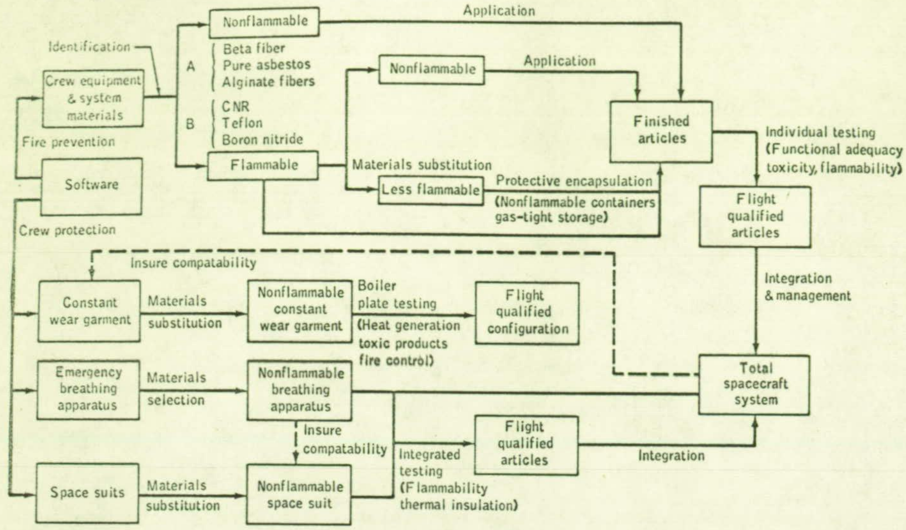


*Figure 7. Format for materials testing and substitution program.*

of glass cloth fabrics — is the determination of particles being emitted by samples during abrasion or wear testing. This information is used to verify that resulting medical problems cannot arise and also to evaluate possible perturbations to environmental control systems.

## MATERIALS

Materials under investigation for protective clothing construction are Beta-fiber cloth, Armalon, asbestos, Kapton, metallic fabrics, melds of asbestos, Beta, Teflon, polybenzimidazole (PBI), metallic fibers, quartz, and boron nitride — and other inorganic fabrics, elastomers, and adhesives. The end result sought is a nonflammable protective garment that will provide greater comfort and safety in potential fire areas, and will provide increased abrasion resistance for longer durability.

Beta is the material presently considered for outer layers of all flame-protective clothing. Beta is available as fabric, cords, braids, tapes, and webbings. It is nonflammable, but has low abrasion resistance (about one-eighth as abrasion resistant as nylon) and requires reinforcement or replacement with metal fibers in areas of high abrasion to increase its source life and to minimize the quantity of abraded Beta particles loose in the spacecraft cabin. Coatings of carboxyl nitroso rubber (CNR) are also being investigated for increasing abrasion resistance and reducing particle discharge. Table 1 compares coated Beta, uncoated Beta, and nylon. Beta has been fabricated into webbing in which inserts of nylon fiber or metallic fibers are woven into areas that are to pass through high-abrasion hardware, such as buckles and metal O-rings.

One of the development contracts that NASA has with industry is for Beta X4190B fabric. Flame-protective clothing has been fabricated from this material, and the initial recommendation is to replace Military Specifi-

TABLE 1. *Comparative Abrasion Resistance of Uncoated Beta, CNR-coated Beta, and Nylon*

| Samples | *Abrasion** *(cycles)* | *Wear†* *(cycles)* |
|---|---|---|
| 4190B, Beta, uncoated | 254 | 63 |
| 4190B, Beta, CNR-coated | | |
| 0.003-in. coating | 625[a] | 424 |
| 0.005-in. to 0.006-in. coating | 355[b]<br>978[a] | 833 |
| 0.007-in. to 0.009-in. coating | 426[b]<br>2,225[a] | 1,172 |
| 0.010-in. to 0.011-in. coating | 2,600[a] | 5,000 |
| Nomex nylon | >1,924 | 320 |

* Tabor 500-g weight wheel.
† Inflated diaphragm, 2-lb weight, 5 psia.
[a] Fabric failed.
[b] Coating failed.

cations MIL-C-508 and MIL-C-7219, Type 3. The basic fabric is made from a Beta 150 1/0 in a 70 by 70 plain-weave pattern. As a backup to this fabric, a Beta 450 high-twist yarn is under development to supply a fabric with greater durability.

Beta-fiber textile structures are under evaluation for flight garments, chamber observer garments, space suit underwear, gloves, socks, zipper tapes, sewing threads, a communications carrier, seam-binding tapes, wire-lacing cord, a lithium hydroxide canister filter, and crew couch padding, and as thermal insulation within the spacecraft cabin.

Many of the textile configurations required for these applications are not available in Beta fiber, making it necessary to go through a period of sample development to provide satisfactory materials for further evaluations. Developing the textile configurations does not require the advent of new technologies, but does require the mechanics of making up the proper structures. Once a particular textile form is considered satisfactory for application, the task remains to develop a specification and source of supply for the material.

One application of Beta fiber is in constant-wear garments (flight coverall and chamber observer garments). Examples of these garments are shown in Figures 8 to 10. The garments are nonflammable, but because of their lightweight construction, they do not provide an efficient thermal barrier, and physiological problems of irritation occur with some types of constructions and fibers.

Although Beta fabric is nearly twice as heavy (2.54 g/cc) as nylon, it has a higher melting temperature (1,550° F), with a useful environmental temperature between −250° and +1,200° F. It is completely nonflammable under all oxygen tensions and has a vapor transmission rate of ¼ lb/yd²-hr.

Impingement tests indicate that asbestos and asbestos/aluminum provide good thermal barriers. Figure 11 shows three space suit layups. Sample 3 is similar to Sample 2, except for the addition of one layer of 3-mil

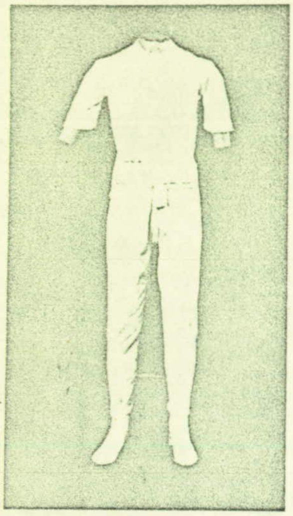

*Figure 8. Under garment.*

*Figure 9. Flight coverall.*

*Figure 10. Chamber observer garment.*

aluminum. Figure 12 shows time/temperature data on three space suit layups.

The present Beta fabric, although it is nonburning, does not present much of a heat barrier in the presence of fire. The National Aeronautics and Space Administration and industry have developed a three-dimensional fabric, which does present a heat barrier. In tests, the applied temperature outside was 1,200° F. The fabric maintained a temperature differential between 500° and 600° F across ⅛ in. of the material after a 10-min exposure.

Beta fabric has good sewing characteristics, but the speed of the sewing machine must be cut from 5,200 to 200 stitches per minute. No special method or equipment is required to cut the cloth. Scissors or shears can be used to cut single ply, but an electric cutting knife with a high-speed steel cutting blade is recommended for multi-ply cutting.

Melding Beta fabric with asbestos results in a noncompressed material, which weighs 13 oz/yd² and provides a temperature differential of 1,100° F after a 5-min exposure to an 1,800° F fire in an oxygen environment of 20 psia. Most pure commercial asbestos fabrics contain binders that will burn in an oxygen atmosphere.

Asbeston, a commercial asbestos which is noncombustible and has a melting temperature of 3,000° F, is available. Its useful environmental temperature is from −200° to +2,400° F. Asbeston has a density of 2.10 g/cc and a vapor transmission rate similar to cotton. National Aeronautics and Space Administration engineers have tested this asbestos material with a 140-lb warp and a filling of 80.

Asbestos has the disadvantages of poor tensile strength, poor sewing characteristics, and low abrasion resistance. These disadvantages are being overcome by a development effort to meld asbestos with Beta fabric



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bulky cloth, which weighs
The fibers are also incorpo
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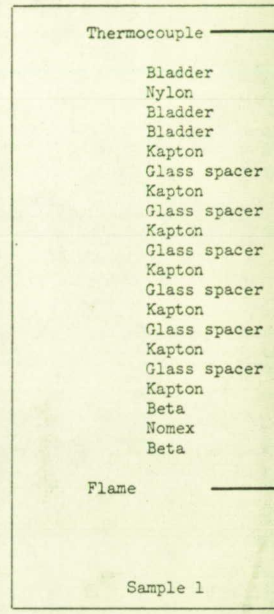


*Figure 11.*

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and with other fibers to increase total fabric strength. The result is a bulky cloth, which weighs 12 oz/yd$^2$, and has excellent thermal properties. The fibers are also incorporated in a composite fabric, of which one surface is predominantly filament Beta and the other is soft, bulky, and fibrous. The hard surface is used on the outside of a garment when abrasion and snagging problems exist.

Also under development is an asbestos web sandwiched between two layers of Beta fabric. The layers are linked mechanically by machine with glass thread. The design goal for this material is a 1,600° F temperature differential after a 30-sec exposure to an 1,800° F flame in an oxygen environment of 19 psia.

| | Sample 1 | Sample 2 | Sample 3 |
|---|---|---|---|
| Thermocouple | | | |
| | Bladder | Bladder | Bladder |
| | Nylon | Nylon | Nylon |
| | Bladder | Bladder | Bladder |
| | Bladder | Bladder | Bladder |
| | Kapton | Kapton | Kapton |
| | Glass spacer | Glass spacer | Glass spacer |
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| | Kapton | Kapton | Kapton |
| | Beta | Nomex | Nomex |
| | Nomex | Beta | Beta |
| | Beta | Beta | Beta |
| | | Asbestos | Asbestos |
| Flame | | Asbestos | Asbestos |
| | | Asbestos | Asbestos |
| | | Beta | Aluminum Foil |
| | | | Beta |

*Figure 11. Three samples of space suit construction.*

In conjunction with Beta fabric, super alloys and coatings are under development. A flame-resistant metal or metal-glass blended tape is necessary in areas where Beta fabric alone would be subjected to high abrasion.

Blending Beta material with Chromel-R fibers has produced a fabric with greater tensile strength and higher abrasion resistance than Beta fabric alone. The present configuration is for use in high abrasion areas, such as sections of webbings that must pass through buckles. Beta, in such applications, abrades badly and sends glass particles into the atmosphere, and the tensile strength degrades considerably. Blending with Chromel-R provides a good abrasion coat and prevents flame propagation. Chromel-R is noncombustible with a melting temperature of 2,550° F and a useful environmental temperature between $-320°$ and $+2{,}000°$ F. Soft

and flexible, Chromel-R can be used in woven, knitted, braided, webbing, matted, threaded, and filtered areas. Chromel-R, though metallic, is classed as a conventional fabric with good sewing characteristics. It can be sewn with thread or with self-material. The specific gravity of Chromel-R is 8.1, with an abrasion resistance between that of Beta and that of nylon and a breaking strength of 240 lb (½ mil, 100/yarn, 80 by 80).

Although existing Velcro has numerous applications for garment closures, such Velcro does not pass the present test criteria for flammability; thus, NASA and industry are working together to develop Velcro from less flammable material such as Beta glass, metallic fibers, and PBI. One such blend, which appears promising, utilizes PBI as a hook, Karma or Teflon as a metallic pile, and Beta and Karma as a tape material. The result is expected to be almost flameproof with a melting temperature higher than 1,000° F.

Another phase of the materials development program is to develop carboxyl nitroso polymer rubber, a nonflammable fluorinated terpolymer. This elastomeric material vaporizes at 520° F with an environmental service temperature between −40° and +375° F. It will be used wherever rubber can be employed; for example, foams in pressure point locations or for helmet vent pads, edgelock for use with Beta fabric constructions, adhesives, and as an abrasion-resistant coating for Beta fabric. Carboxyl nitroso rubber molded items, such as boot soles, have been produced in gum form. Nitroso rubber is completely nonflammable in high pressures of pure oxygen.

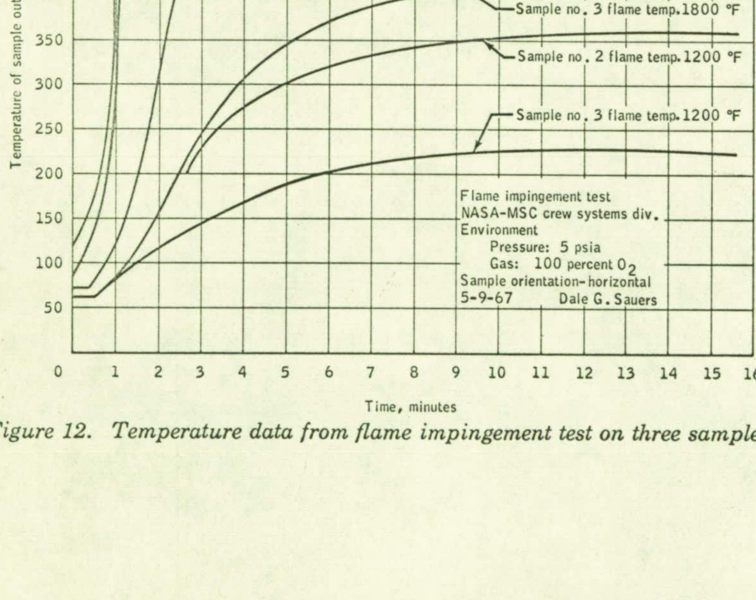


*Figure 12. Temperature data from flame impingement test on three samples.*

Chlorotrifluoroethylene (Kel-F) is under evaluation as a substitute coating material for Teflon in some garment applications. Kel-F has an environmental temperature from $-450°$ to $+450°$ F. Kel-F has a high combustion rate of 0.769 in./sec in a 100-per cent oxygen atmosphere of 16.5 psia when ignited at the bottom, but is self-extinguishing when ignited at the top. Its qualities of abrasion resistance and folding endurance are fair, and its tensile strength is 5,000 psi. Presently, Kel-F is available as a film only.

Polybenzimidazole (PBI) is a synthetic material presently being spun into monofilament and multifilament yarns. This material has been woven into fabrics, webbings, and other useful forms. Monofilament PBI has even been successfully formed into Velcro hooks. This material exhibits physical properties equivalent to those of nylon, but has a useful service temperature of over 900° F. It burns in an oxygen atmosphere, but more slowly than does nylon. Polybenzimidazole webbing is currently being considered for harness applications in the Apollo spacecraft.

## GARMENTS

The Crew Systems Division of NASA MSC is responsible for the development of all NASA flight and chamber garments. This responsibility includes the following items.

### Pressure Garment Assembly

The pressure garment assembly (PGA) is the standard Apollo space suit, the primary function of which is to provide a livable environment (3.7 psia) under vacuum conditions. It continues to contain some flammable materials, such as the space suit bladder — for which no replacement exists — but is covered with a thermal protective cover layer, which is relatively nonflammable and is designed to prevent degradation or auto-ignition of the interior flammable materials.

### Thermal Micrometeoroid Garment

The thermal micrometeoroid garment (TMG) is the outer garment worn in extravehicular activity, including all lunar exploration. This garment must protect the crewman against the rigors of meteoroid bombardment and the $\pm 300°$ F temperature extremes of deep space environs. The thermal protection is provided by multiple layers of aluminized polyimid film interspersed with glass marquisette spacer material. Flame protection is provided by two double layers of Beta fabric on the garment exterior. Chromel-R fabric is used in high-abrasion areas to provide abrasion protection to the Beta material.

### Constant Wear Garment

The constant wear garment (CWG) is an underwear-type garment that is worn during shirtsleeve portions of space flight when the spacecraft is pressurized and the PGA is removed for comfort during long periods of time. Garments have been successfully constructed from continuous

filament, nontexturized Beta knit. Extensive tests have been, and are being, conducted to verify that no adverse dermatological effects result from the use of this material. Prisoners at the Huntsville Prison, Huntsville, Texas, have worn these garments for 30 days and reported no resulting discomfort. Other garments have been worn by astronauts and MSC engineers with similar results. Other types of Beta of knitted construction were found to cause irritation.

Undergarments of Teflon and PBI are all being considered for flight usage.

### Liquid Cooled Garment

The liquid cooled garment (LCG) is similar to the CWG except that it includes a system of liquid-cooling tubes, which are used under "hot-side" temperature extremes to provide astronaut cooling. For this application, a program is underway for the development of high-conductivity tubing from CNR.

### Chamber Observer Suit

The chamber observer suit (COS) is worn in chamber manlocks by observers whose function is to go into a partially pressurized chamber to retrieve an incapacitated test subject. The garment is not designed to provide thermal protection, but is nonflammable.

### Fire Entry Garment

The fire entry garment (FEG) will, in addition to being nonflammable, afford considerable thermal protection to personnel who must expose themselves to the intense heat of a fire. The garment incorporates a Beta inner and outer layer, aluminum layers for maximum lateral heat transfer, and asbestos for low inward heat penetration; the garment is equipped with a hood and visor, thermal boots, and thermal gloves. The garment can also be used with a portable, chilled-water cooling unit and liquid-cooled underwear for better thermal protection over longer periods of time.

### Flight Suits

Flight suits of both one- and two-piece construction have been fabricated from Beta. These items have been worn and have proven very satisfactory to date.

### Other Items

Other items include shorts, T-shirts, and socks. These items are being made from Teflon and Beta for evaluation.

## SUMMARY

Thermal protection is designed into garments as required for end-item applications. Because of weight, comfort, and mobility considerations, thermal protection is omitted where not specifically required, and garments are kept as thin and flexible as possible for those applications where thermal



protection is necessary.
garment layups are show

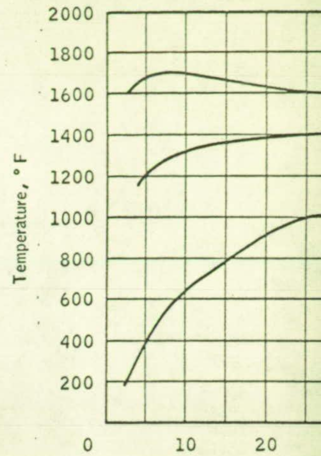


*Figure 13. Temperature data*
*psia oxygen atmosphere.*

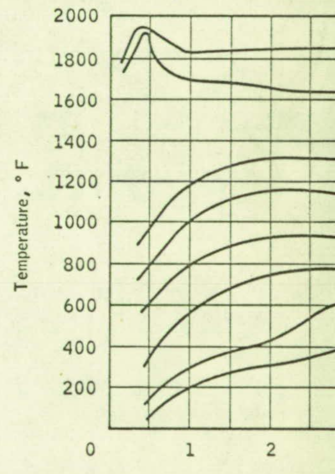


*Figure 14. Temperature data*
*6.2 psia oxygen atmosphere.*

protection is necessary. Time/temperature curves for several lightweight garment layups are shown in Figures 13 to 17.

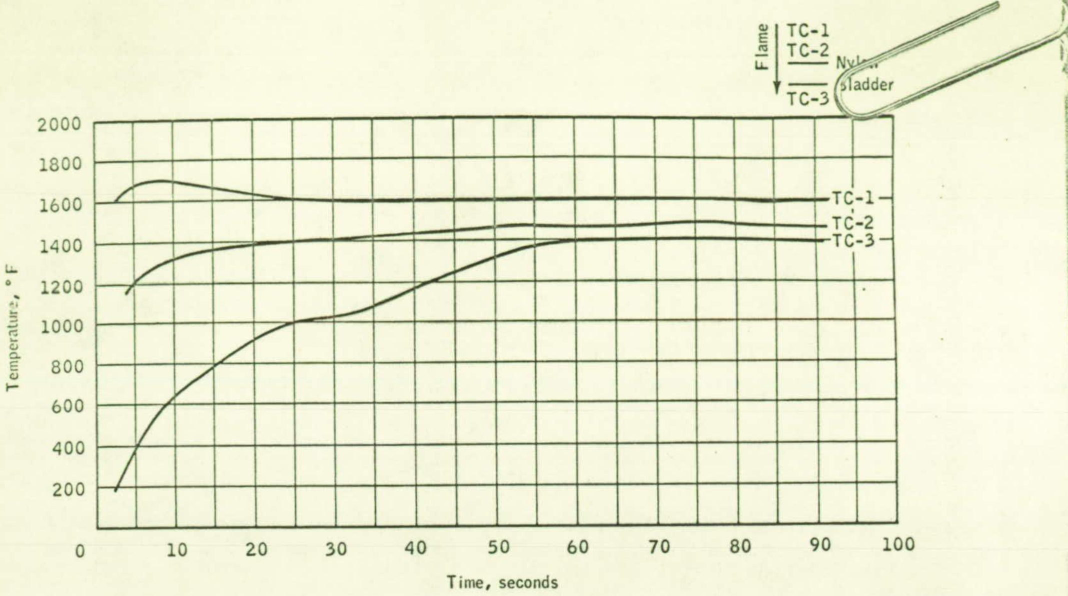


*Figure 13. Temperature data from flame impingement tests on Assembly No. 1 in a 6.2 psia oxygen atmosphere.*

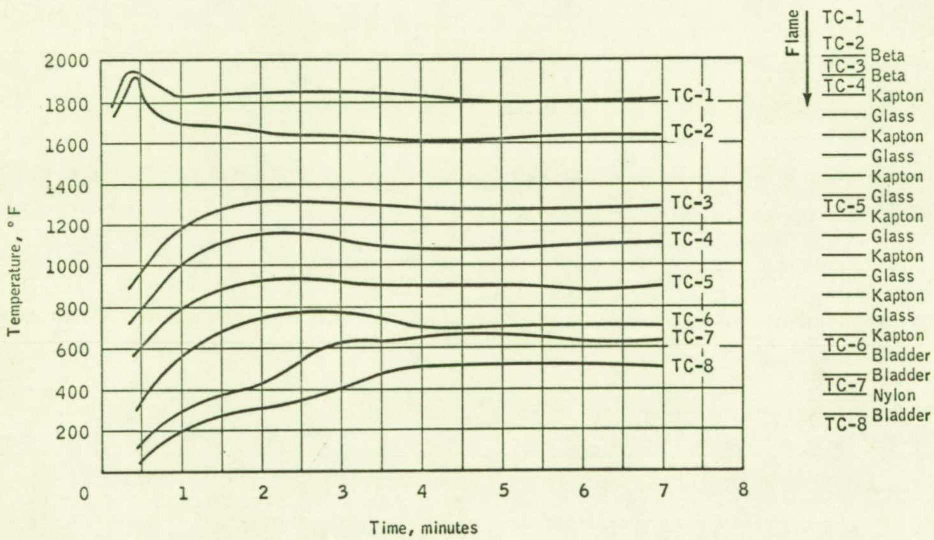


*Figure 14. Temperature data from flame impingement tests on Assembly No. 2 in a 6.2 psia oxygen atmosphere.*

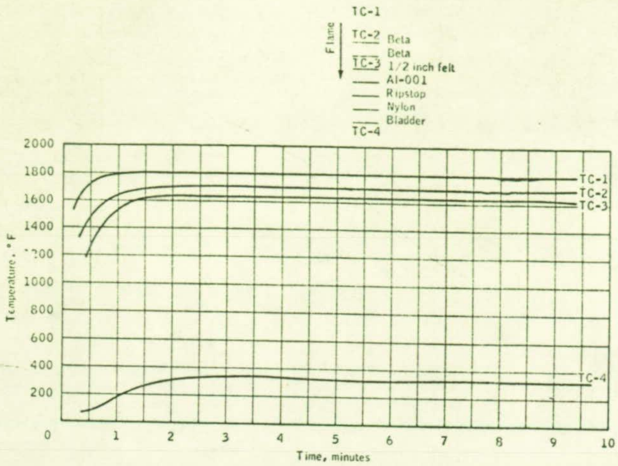


*Figure 15. Temperature data from flame impingement tests on Assembly No. 3 in a 6.2 psia atmosphere.*

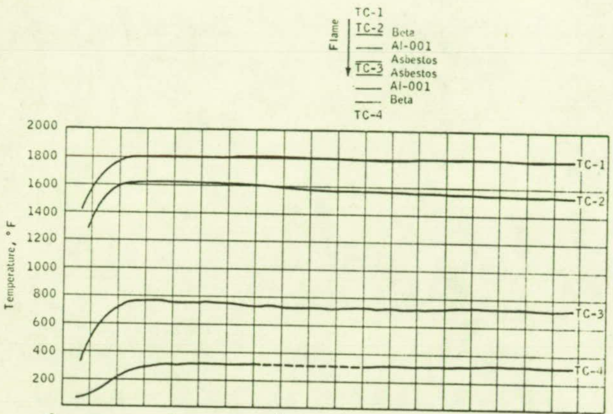


*Figure 16. Temperature data from flame impingement tests on Assembly No. 4 in a 6.2 psia atmosphere.*

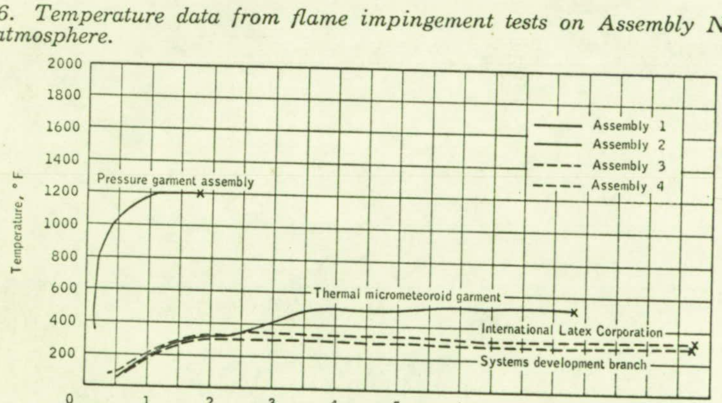


*Figure 17. Comparison of temperature data from low-reading thermocouples of Assemblies 1, 2, 3, and 4.*

# *The Spread*

J. H. McGUIRE, *SFPI*
*Division of Building Rese*
*National Research Counci*

Full- and quarter-sc
semblies, using vario
ing materials, yielded
and large-scale tests,
effects of floor coveri

TESTS to determine co
istics of materials hav
test results do not agree c
questionable, the principal
required concerns how to
ceiling linings and floor co

The average room, ha
enough combustible mate
of the building lining ma
of such a fire and the tim
complex, however, that no
been derived.

The corridor differs fro
combustibles in it; it can,
sustain or propagate a fire
limiting combinations of c
propagate fire indefinitely
ings in the corridor woul
Test of Surface Burning
No. 255 (also UL 723 and
for Surface Flammability
Source, ASTM E162. In
identical scales.

SMA

To expedite results and
carried out on a small sca

NOTE: This paper is a con
tional Research Council of Ca
of the Division.